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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Controlled Lubrication in Anti-Friction Bearing Design

Carbon Residue

Its Effect and Determination

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

Ball and Roller Bearing Efficiency

MAXIMUM PROTECTION of any type of anti-friction bearing is necessary if it is to justify its first cost. This can only be assured by use of seals and closures designed effectively to prevent entry of abrasive or non-lubricating foreign matter.

The adoption of the ball bearing in electric motor construction and the practicability of the roller bearing to steam railway, paper mill and steel plant machinery, have logically led to careful study of sealing methods and the means to enable both bearings and lubricants to function with positive dependability.

The success which has been attained is proved by the ever-increasing popularity of ball and roller bearings. The Petroleum Industry is proud of its part in this success; for the manufacture of ball and roller bearing lubricants has been one of the primary research problems before the refinery chemist and lubricating engineer during the past few years.

THE TEXAS COMPANY

TEXACO

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Controlled Lubrication in Anti-Friction Bearing Design

FRICTION reduction is the paramount factor in economical operation of virtually any machine, for friction is indicative of wear. Friction may be also regarded as the criterion in connection with power consumption. In other words, increase in friction between any two or more wearing surfaces, will increase their resistance to motion with respect to one another, requiring more power to accomplish the desired results. The salient factor in the reduction of friction is effective lubrication. It is assured where mechanical conditions are scientifically correct and capable of permitting the lubricant to perform its intended function. Where bearings are concerned the motion involved may be either sliding or rolling. The anti-friction bearing is designed to develop rolling motion in the interest of reducing friction.

The fact that the anti-friction bearing, whether it be of the ball or roller type, will normally involve a minimum of friction, will be an asset in its favor wherever the occurrence of wear may be a detriment to productive efficiency and accuracy. Rolling motion will obviously not be prone to give rise to as much wear as will sliding motion.

On the other hand, rolling motion in an anti-friction bearing must be maintained as perfectly as possible, for if it ceases in the case of any particular element as a ball or roller, more or less sliding will occur, to the detriment of the contact surfaces of itself as well as the raceways. This can be prevented by judicious study of sealing media, and designing with a view toward enabling the seal to function in conjunction with the lubricant in preventing entry of abrasive or non-lubricating foreign matter, water, steam or acids, according to the ultimate location of the bearing.

FUNCTION OF LUBRICATION

The purpose of lubrication is to facilitate as easy rolling as possible. To enable this, however, all the surfaces (which are of a highly polished nature) must be in as perfect condition as practicable.

Minimum clearance is an aid to proper functioning of such bearings, for the occurrence of any play between the component parts would tend to set up a certain amount of pounding which would be detrimental to effective operation. In other words, all motion must be as nearly akin to perfect rolling as possible.

As a general rule as light a lubricant should be used as can be successfully retained in such a bearing, commensurate, of course, with the temperatures, speeds and pressures involved.

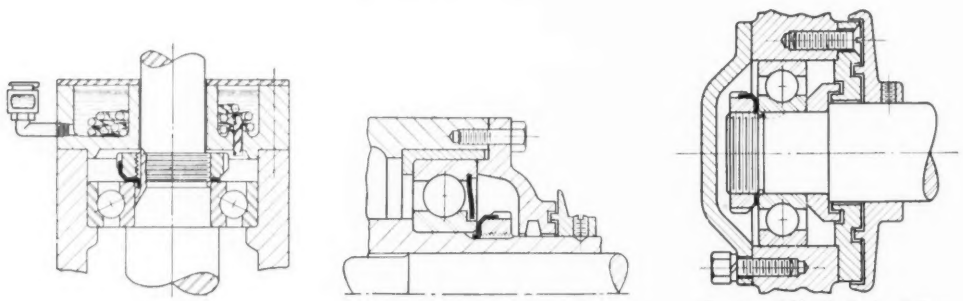
Ball Bearing Requirements

Certain authorities feel that ball bearings involve the least possibility of friction due to the fact that there is little or no end thrust developed, with the exception of that which might occur from some external cause. As a result, the lubricant in such bearings serves more nearly

the purpose of acting as a seal and metal-protecting medium.

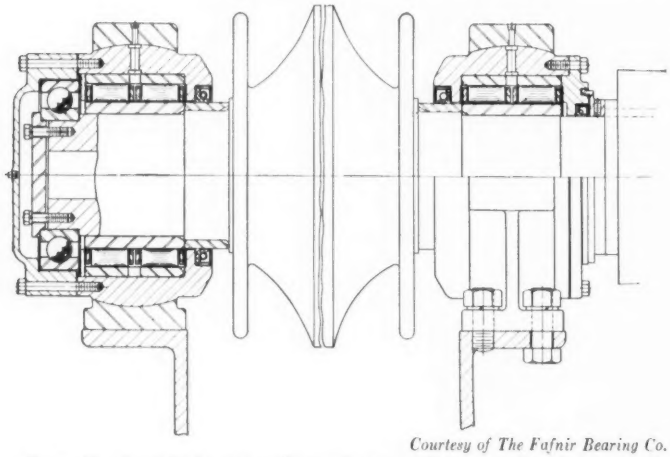
In view of this fact, and to reduce the possibility of the development of abnormal internal friction within the lubricant, it is advisable to pay careful attention to the amount of lubricant used.

Leading manufacturers advise that where oil is employed, the housing should generally be filled to a level just sufficient to submerge half the surface of the lowest ball. Oil lubrication is widely recommended for high speed operations, or where service temperatures exceed 200 degrees Fahr. It is well to remember that the viscosity or body of the lubricant becomes a decided criterion as higher speeds are approached, due to excessive churning and development of heat through internal friction.



Courtesy of Marlin-Rockwell Corp.

Fig. 1—Typical bearing mountings for vertical and horizontal installations. At left is shown a high speed installation which provides for filtered, drop by drop oil feed. Center view shows a simple flinger and "Lubriseal" adaptable to bearings where sealing may be difficult. At the right, flinger design for very dirty or wet conditions where considerable speed is involved, is shown.



Courtesy of The Fafnir Bearing Co.

Fig. 2—Showing roller bearing application to paper mill press roll wherein heavy loads must be sustained. Grease lubrication is employed, being retained by leather seals. These also prevent entry of water.

Under extremely high speeds sight feed drip oil lubrication has proved to be very satisfactory in reducing churning and heat development.

When grease is used, a somewhat greater amount is permissible; the housing being charged to one-quarter to one-half full. Use of greater quantity may lead to drag, temperature rise and abnormal power consumption. Grease is advantageous for slow speed service or when there is danger of contamination with dirt and water, due to its sealforming properties. The heavier the product, the better the seal. Grease also can be very much more effectively retained in a non-oil-tight housing; on the other hand, dirt or grit that finds its way into a grease lubricated bearing has no means of settling out, but is always held in suspension, being carried back into the bearing repeatedly.

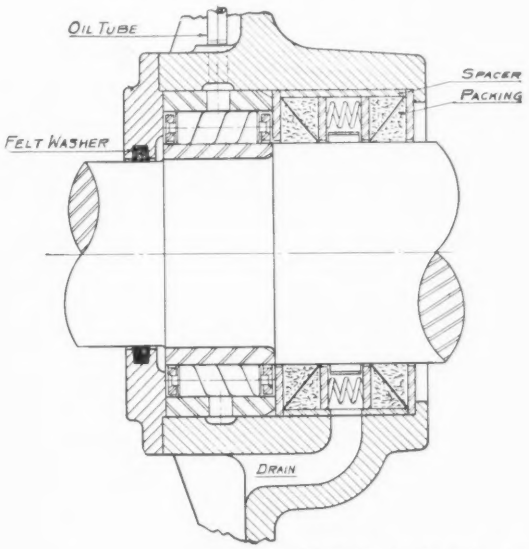
Roller Bearing Service

In the roller bearing, lubrication by means of oil is subject to much the same conditions as stated in connection with ball bearings. Where end thrust may develop to an appreciable extent, however, due to difficulty in keeping the rollers in alignment, or where pressures or temperatures may be high it is the opinion of certain authorities that it will be conducive to better lubrication if comparatively heavy oils are used. Under such conditions the use of straight mineral lubricating oils of as high as 750 seconds Saybolt viscosity at 100 degrees Fahr., are advocated. Even mineral cylinder oils of a high degree of purity may be necessary under conditions of extremely high duty, pressure or temperature.

The selection of heavier oils for roller bearing lubrication should be carried out with the utmost care by careful observation of bearing temperatures, for it is very possible to over-estimate the conditions of operation, with the result that an excess of internal friction may be developed.

Where such bearings may be exposed to consistently high temperatures, pressure circula-

tion of a comparatively fluid oil has been found to be conducive to lower actual bearing temperatures, there the oil acts directly as a coolant; to aid it in this function, it may in turn be cooled prior to recirculation.



Courtesy of Roller Bearing Co. of America

Fig. 3—Showing a Heliflex bearing as applied to trunnion of a laundry machine. Seal is maintained by a spring installed between spacer packing elements. Note also the drain to carry off any water.

Lubrication Charts

The lubrication charts as prepared by some of the leading bearing manufacturers will materially facilitate selection of the proper grade of lubricant to meet any specific operating condition in an anti-friction bearing, especially from the viewpoints of speed and temperature.

In part, these charts attack the problem from the same angle. Each is so unique in its arrangement, however, and so particularly applicable to the various types of bearings as to be of inestimable value in formulating an opinion as to the physical characteristics of the lubricants required. The chemical properties of all will hold true regardless of bearing design and construction.

As a general rule, greases which are comparatively fluid in consistency will meet average operating conditions where the lubricant must readily cover the entire surfaces of the balls or rollers and not tend to pack in the housings or raceways, as might occur with more viscous products of this nature which would have less of a penetrative ability.

On the other hand, under conditions of high temperature, as, for example, in steel or cement mill service, it might be necessary to resort to greases of greater body to withstand the thinning-out effects of heat, and prevent the consequent entry of dust or dirt.

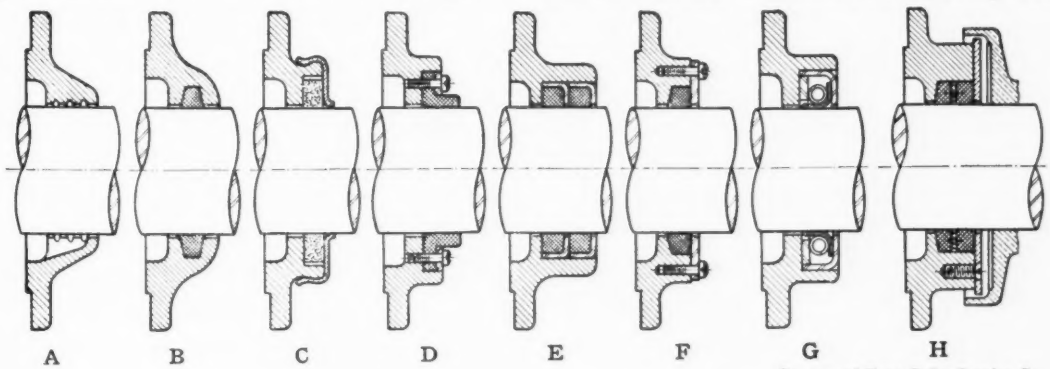
CONSTRUCTIONAL FEATURES

Particular makes of ball bearings will differ according to the design of the housing and type of lubricant seal employed.

In the roller bearing, however, the design of the rollers will be an added characteristic. In general, these will be either solid or helically wound. Helical rollers are always cylindrical in shape, the distance between the inner and outer raceways being uniform throughout the length of the roller. Solid rollers, on the other hand, may be either cylindrical or tapered according to the type or design.

Irrespective of the nature of the rolling elements, anti-friction bearings in general will be carried or housed in much the same manner, i.e., in suitable containers comprising raceways or cages. In a typical design the inner race will fit on the shaft or journal, the outer being held by the frame or other rigid part of the bearing.

Between these so-called raceways are located the balls or rollers. These are kept in their



Courtesy of Hyatt Roller Bearing Co.

Fig. 4—Typical housing covers for Hyatt installations. A shows use of capillary grooves, B a simple felt seal, C a cork washer installation, D cupped felt washer, E the use of 2 felt rings and retainer cups. F a felt ring retained by a demountable cover, G the use of a leather washer held snugly against the shaft by a coil spring, and H a slinger mounted on shaft in conjunction with 2 felt rings. This is recommended for water exclusion.

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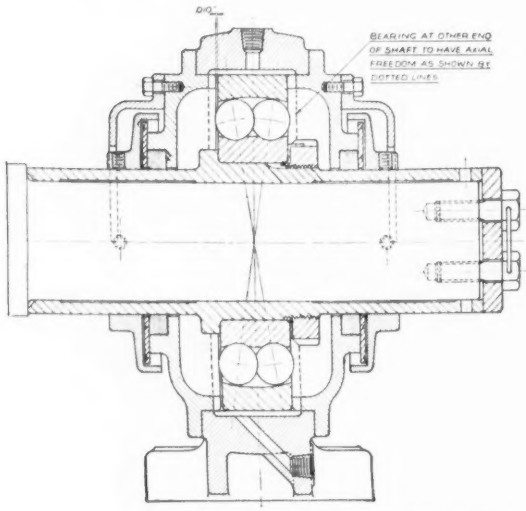
proper position with respect to the races and to each other by the separator, cage or retainer. Rotation of the shaft sets up a rotary motion between the rolling elements and the respective inner and outer surfaces of the raceways.

Anti-friction bearings involve rolling contact



Courtesy of SKF Industries, Inc.

Fig. 5—Showing a type of straight bore bearing sleeve installation used where bearings must be removed periodically under dirty service conditions. This insures protection against dirt.

from a theoretical point of view. In the ball bearing, the contact surface is in the form of an elipse.

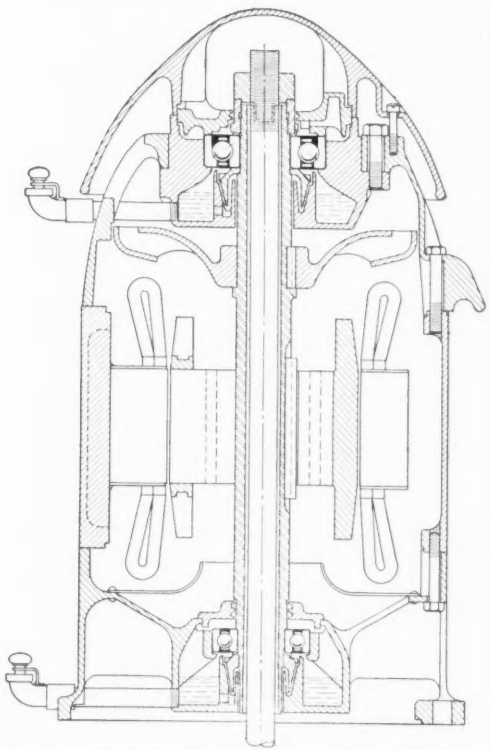
The roller bearing, however, involves theoretical line contact between the journal or shaft elements and the outer raceway. In operation this will not strictly prevail, although in the properly constructed ball bearing sliding motion will be practically negligible. In certain types of roller bearings, however, there may be more possibility of sliding motion, especially where end thrust may prevail to any extent.

Rolling friction becomes more nearly possible when the rollers are maintained in as nearly as practicable perfect alignment with the shaft, and deflections under load are reduced. Certain authorities feel that it is impossible to entirely eliminate such deflections, hence they believe some sliding motion will always occur.

This is not serious when we realize that other conditions of operation may vary widely, as for example, the speed of operation or the temperature. Either in its normal variation between minimum and maximum production periods, or summer and winter ranges may have considerable effect upon the performance of a lubricant within an anti-friction bearing.

Low temperatures may lead to sluggish actions in certain products, with consequent increase in power consumption. This latter, if a considerable number of bearings are involved, may become quite a factor in its cumulative effect. Hence the advisability of always choosing low pour test oils, or greases prepared with such oils where comparative fluidity, regardless of temperature, is desirable.

Operating speeds, in turn, will require careful consideration of the viscosity of any lubricating oil employed for such service. The higher the speed, for example, the lower should be the viscosity or body of the oil down to, of course, a certain definite limit, let us say, 100 seconds Saybolt at 100 degrees Fahr. The reason for this is that as speed of operation is increased the more rapidly will the lubricant in such a bearing be agitated or churned about, especially if the bearing has been overcharged. Such motion will be bound to lead to an increase in internal or fluid friction within the lubricant



Courtesy of The New Departure Manufacturing Co.

Fig. 6—Vertical motor bearing, designed for deep well pumps. Bearings are lubricated with oil from reservoirs located below each bearing. Tapered slingers, fastened to the motor shaft, draw oil from reservoirs to bearings in a fine mist. Reservoirs are large enough to insure operation for extended periods without attention.

and consequently an increase in temperature. It is for this reason that oils of relatively low viscosity are preferred for the lubrication of high speed anti-friction bearings where installed in machine tools and certain types of textile machines, or as a component of greases

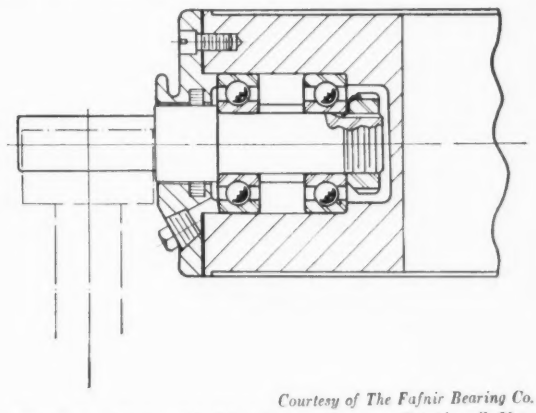
designed for similar service in electric motor bearings which may be exposed to low atmospheric temperatures.

IMPORTANCE OF LUBRICANT SEALS

The development of the heavy duty roller bearing has been particularly noteworthy from the viewpoint of the efforts of the designers to work out effective lubricant sealing features in the form of labyrinths, slingers, seal rings, and cup leather seals. Retention of the lubricant was early appreciated as being a most important feature. Obviously, protection of the surfaces of the bearing elements could not be assured were leakage of lubricants to prevail, and with this lack of protection, failure of a bearing under intense load might easily occur.

It was also important to study sealing devices by reason of the high temperatures under which so many steel and paper mill bearings, in particular, must operate. The effect of such temperatures is to reduce the viscosity or consistency of any lubricant. The extent to which this will occur depends, of course, upon the original body of the product. Unless the latter is of the nature of steam cylinder oil with a viscosity in the neighborhood of 130 seconds Saybolt or above, at 210 degrees Fahr., at steel mill temperatures considerable leakage may result from certain types of bearings. It is for this reason that steam cylinder stocks are used in certain grades of roll neck greases.

Where an adequate bearing seal can be provided, as is customary in the design of the majority of roller bearings employed in such service, leakage, even under extreme tempera-

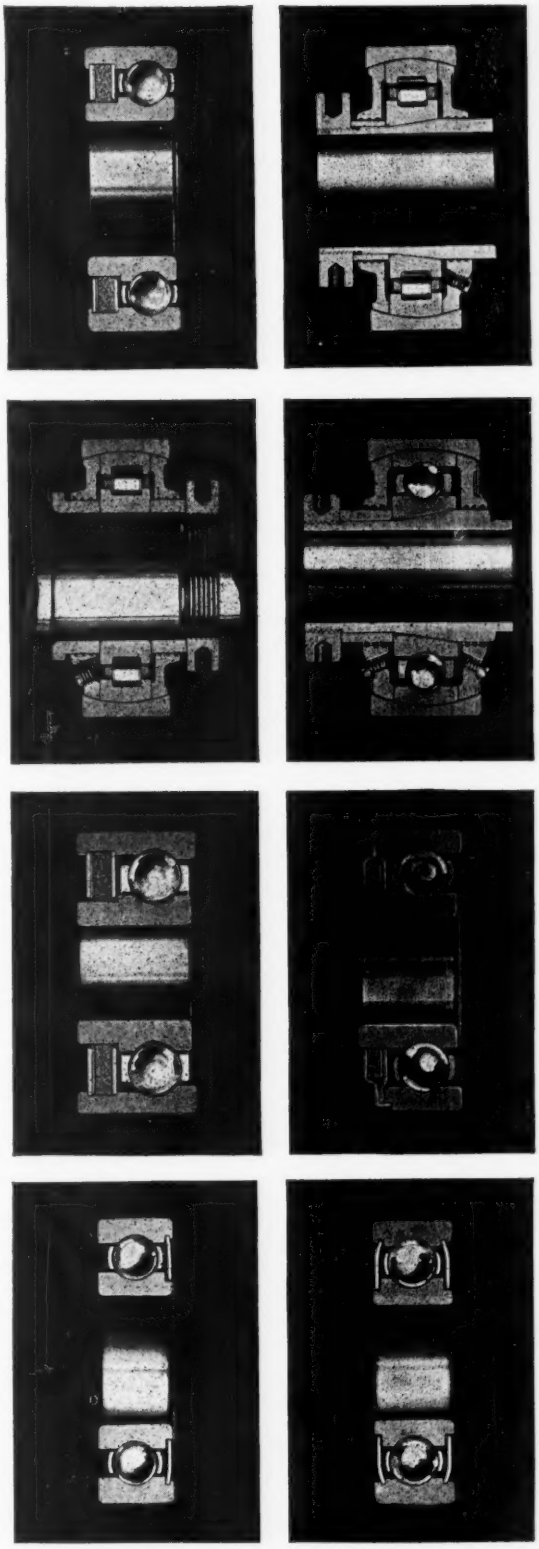


Courtesy of The Fafnir Bearing Co.

Fig. 7—Installation of ball bearings on a paper mill table roll. Note bearing application is made to a live roll in a stationary journal rather than directly to the usual live journal.

tures, can be prevented to a marked degree. In this connection, a discussion of the various types of seal design will be of particular interest.

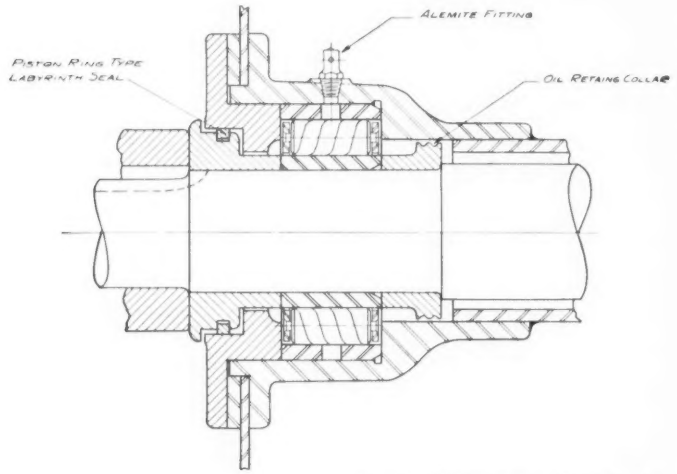
In the earlier developments of sealing media, felt and leather washer and grease-groove seals proved their adaptability and were compara-



Courtesy of Norma-Hoffmann Bearings Corp.

Fig. 8—Showing a number of Norma-Hoffmann bearing designs and means of applying "GreaSeal" felt protected packings to insure against entry of contaminating foreign matter.

tively inexpensive and simple in design. By virtue of these advantages, they are still retained by many bearing manufacturers. Since their development, however, other types of seals have come into usage including metallic rings similar to piston rings, mercury baths



Courtesy of Roller Bearing Co. of America.

Fig. 9—Showing Heliflex bearing mounting and method of sealing by means of piston ring type labyrinth seal at one end, with oil retaining collar at the other.

in connection with vertical installations, and metallic springs for the purpose of maintaining the adjustment of felt, leather, rawhide and cork with respect to shafting, journals or roll necks. Composition rings of micarta or bakelite have also proved of value as an oil seal, or to protect a grease-lubricated bearing against entry of water.

The primary objective in the selection of a suitable grease or oil seal is to obtain a design which will not show material wear in service, otherwise the purpose may be more or less defeated. Washer type felt or leather seals will have this tendency, although the rate of wear will depend upon the quality of the material. Where adjusting springs are used in connection with similar material, to automatically keep the seal in close contact with the shaft or journal surface, and thereby compensate for wear, dependable retention of lubricant is accomplished.

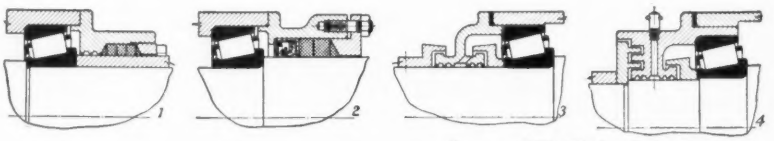
Grease groove seals present a comparatively simple means of overcoming leakage of lighter lubricants under normal temperature conditions. They are also relatively simple and inexpensive to design. On the other hand, they require attention at periodic intervals, for the purpose of renewing the sealing grease. Otherwise, possible glazing of the surface of this latter where it comes in contact with the rotating shaft might result in sufficient clearance to allow leakage of the bearing lubricant. Very heavy bodied greases of high melting point are adaptable to service as grease seals, provided they show no tendency to separate oil from soap, and contain no material which might prove abrasive to the shaft surface. Grease grooves can also be used together with felt washers in certain types of service.

While spring adjusted seals insure more uniform contact between the sealing medium and the shaft, journal, or roll neck, they involve more constructional details and consequently can normally be expected to be more expensive than the more simple types of washer seals.

Drain Plugs

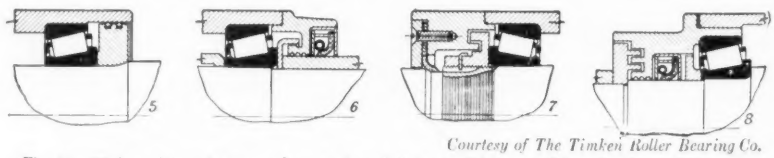
By virtue of the necessity for periodic cleaning of bearings subjected to heavy duty under dirty conditions, it is highly advisable that suitable provisions be made in the base of the housing for drainage of lubricant and slushing fluid. Normally a suitable plug which can be securely screwed into a drilled and tapped hole will serve the purpose and prevent leakage during operation. Oftentimes this can be elaborated upon where oil is employed for lubrication, by an arrangement of nipples and pipe fittings terminating in a sight gauge glass. In this way not only is cleaning facilitated, but also the oil level in the bearing can be observed.

It is important to remember that the maximum protection of any anti-friction bearing is



Courtesy of The Timken Roller Bearing Co.

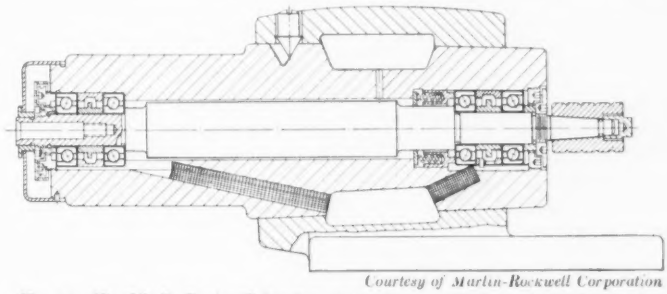
Fig. 10.—A number of Timken bearing closure designs. (1) is a stuffing box type, (2) is similar to above except that a leather seal retained by springs is employed, (3) shows annular groove closure for high speed bearing oil applications and (4) is a combination annular groove and labyrinth closure for high speed oil lubricated bearings.



Courtesy of The Timken Roller Bearing Co.

Fig. 11—(5) is a piston ring type closure where it is impossible to use felt or leather, (6) is a combination metal stamping annular groove and leather closure for use where retention of lubricant is important, (7) shows a combination of machine parts and leather seals for vertical applications and (8) is an annular groove and leather seal design similar to No. 6.

only assured by maintenance of the lubricating system as free from foreign matter as possible. In certain types of operation this can be more easily accomplished than in others; the extent to which dust, dirt, metallic chips or scale may be present in the air or thrown onto the bearing will, of course, be an influencing factor. In steel mill operations this must be particularly borne in mind in the design of anti-friction bearing seals as well as provisions for cleaning, for there is always possibility of entry of non-lubricating abrasive impurities where such a bearing is not properly sealed. The detrimental results which would develop in the form of scored bearing elements, misalignment, and the necessity for bearing replacement, with the attendant effect upon production, can be readily realized.

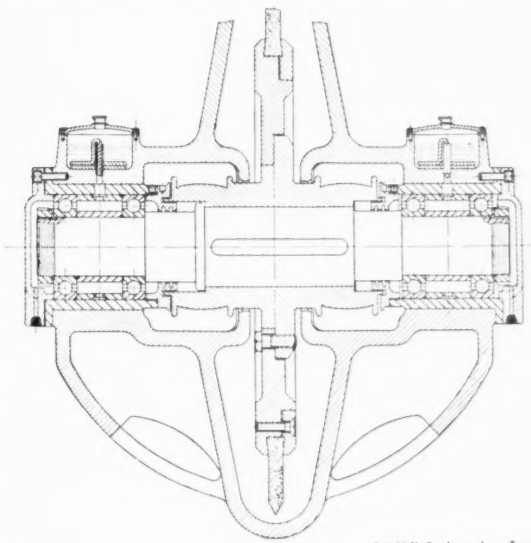


Courtesy of Marlin-Rockwell Corporation

Fig. 13—The Marlin-Rockwell bearing design for very high speed grinder service. Filtered oil is delivered drop by drop. Excess oil leaks out through the seals, thus cleaning them. Note elaborate sealing arrangement to prevent entry of contaminating foreign matter.

Probably the most intensive duty to which such a bearing can be subjected is continued churning of abrasive foreign matter with oil or grease in intimate contact with the highly polished bearing elements.

For the reason that it is not always possible to effect the requisite degree of sealing or to depend upon the seal being in proper condition at all times, bearings in service such as is involved in the average mill should be flushed and cleaned at periodic intervals. Care should be taken to use a light oil for this purpose. It is not advisable to use solvents such as gasoline or carbon tetrachloride, for these would tend to dissolve the mineral oil content of any grease used, to leave a residue of insoluble soap. The frequency, of course, will depend upon the design of the bearing, the type of seal, the extent to which dust, dirt, scale or water may be present, and the nature of the lubricant. Some classes of steel or paper mill service will be more subject to contamination of lubricants than others. Roll neck and table roll bearings, for example, may suffer in this respect more than those used on cold saws, although the use of oil slingers fastened to shafts or journals have been found to effectively prevent entry of too much foreign matter. Yet, even with such precautions, cleaning of the bearings should not be neglected, for experience has proved that their life can be materially lengthened by such attention.



Courtesy of SKF Industries, Inc.

Fig. 12—Illustrating SKF bearing mounting on a light duty, high speed thread grinder. Considerable care has been exercised in design of enclosures to prevent entry of dirt or moisture.

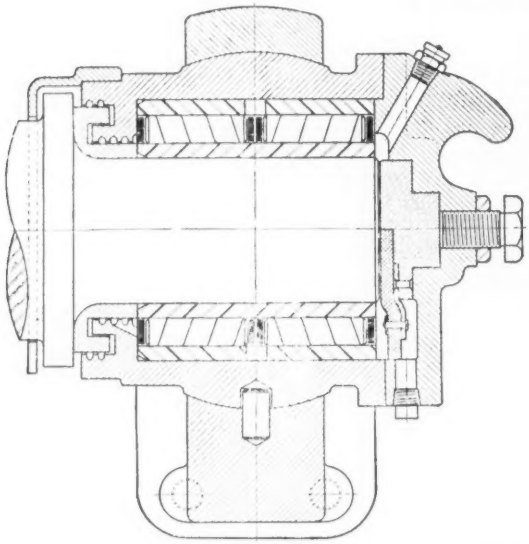
Venting of Bearings

In the operation of roller bearings, particularly where external heat conditions may prevail, vent holes have also been found of material advantage in relieving possible pressures within the bearings, and back pressures upon the lubricants. Vent holes will be particularly advisable on grease lubricated bearings, as an indicator to operators in filling. Were pressure to prevail, with no provision for its relief, proper filling might easily be prevented. Elimination of such pressures within a bearing also serves to prevent possible leakage in event of overheating from external or internal sources, due to the fact that any expansion of the lubricant can occur freely. Should it be restricted, the development of back pressure with no source of relief might cause leakage around the bearing housing, with even the possibility of impaired lubrication.

APPLICATION OF LUBRICANTS

One of the most frequent causes of difficulty, particularly in the use of grease as a lubricant for ball or roller bearings, is the practice of forcing an excessive amount into the housing by means of a pressure gun or compression cup. Dependent upon the consistency or body

of the grease, this will lead to development of abnormal internal friction within the lubricant itself, to cause overheating. With certain types of grease, abnormal increase in temperature may cause sufficient decrease in body to result in separation of the oil from the soap thereby causing marked reduction in the lubricating value.



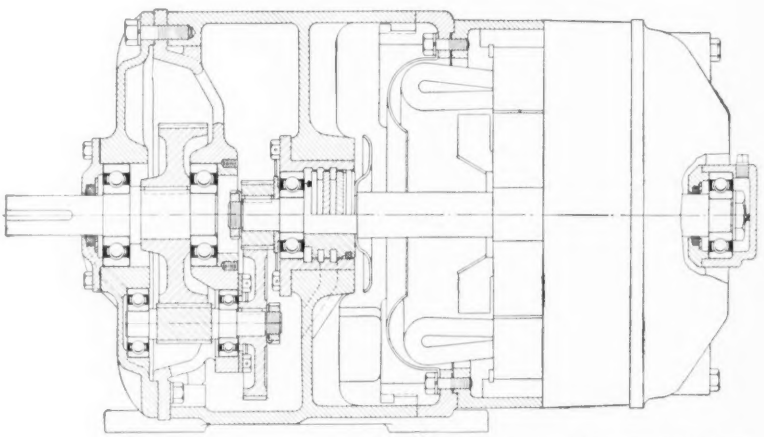
Courtesy of Hyatt Roller Bearing Company

Fig. 14—A paper machine breast roll Hyatt bearing mounting. Note at right wick lubricated adjustable bronze block, which takes up lateral motion of roll.

The resultant overheated condition of the bearing itself may lead some operators to feel that the difficulty is due to lack of lubrication. On the other hand, addition of more grease will only aggravate conditions. There will also be the danger of leakage of a certain amount of the lubricant past the seals. This would be an extremely objectionable feature in electric motor bearings, due to possibility of the lubricant fouling the windings, and in industrial service, as for example, on certain types of textile machines, where such leakage might result in considerable contamination of the goods being processed. For this reason, every effort should be directed to impressing upon operators that all anti-friction bearings under their jurisdiction have a certain limited capacity for lubricants which should not be exceeded. Unfortunately, there is no direct method by which application of grease to anti-friction bearings can be accurately controlled. Recently, however, study of steel mill bearings has indicated that use of vent holes located close to the top of the bearing housing will be advantageous as a means of indicating when a bearing has received sufficient lubrication. Venting leads to a further advantage in that it eliminates possibility of imposing the full pressure of the lubricating equipment upon the seals. In the case of certain types of grease guns, this pressure is extremely high.

Where automatic grease lubrication systems are involved careful study should be made of methods of sealing and construction of closures. Systems of this type are designed to deliver a definite amount of grease at regular intervals. Obviously all bearings served should be as nearly alike as possible in regard to lubricant retention. Otherwise loss of grease might result from those wherein the seals might not be able to withstand the pressures imposed upon the fresh charge of grease. For this reason certain authorities prefer some form of manual control whereby each individual bearing can be lubricated according to its constructional conditions.

Where anti-friction bearings are designed for oil lubrication, of course, control of the level in the housing is more practicable. Normally it is only essential to install an overflow device, with or without a gauge glass attachment at the base of the housing.



Courtesy of The New Departure Manufacturing Company

Fig. 15—A motor and speed reducer ball bearing installation. A slinger seal located between gear chamber and motor housing is provided to keep gear lubricant out of motor windings. This also prevents entry of dust or dirt into the gear housing. The rear motor bearing is grease lubricated.

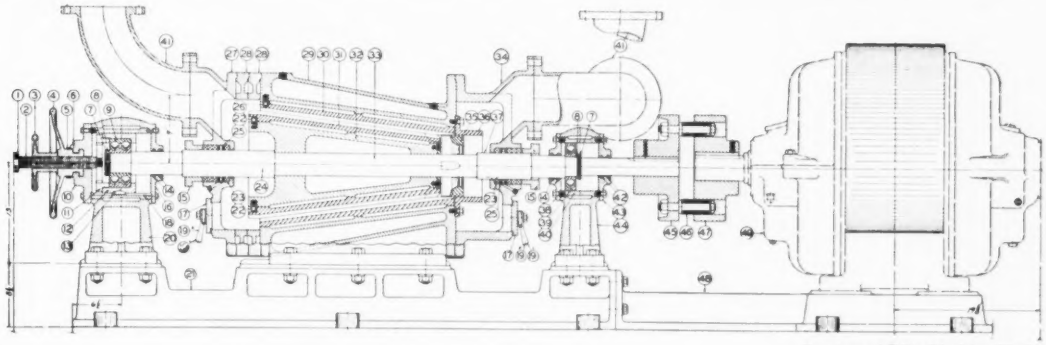
Desirable Properties of Grease

Grease for ball and roller bearing lubrication should be as free from acid forming tendencies as possible in order to insure adequate protection of the highly polished metallic surfaces. In effect, this involves perfect neutrality, and,

of course, the absence of fillers. The presence of any material that might give rise to oxidation and the development of free acidity or to decomposition or settling is also prohibited.

Properly compounded products will meet these requirements satisfactorily under normal conditions of operation, and there should be practically no tendency for them to cause corrosion or pitting of balls, rollers or raceways.

Whatever the lubricant specified, in general, a properly designed ball or roller bearing will require replenishment of this product but once every three or four months, or oftentimes at less frequent intervals if the housing is capable of holding a relatively large volume of lubricant, and an effective seal is maintained.



Courtesy of Dilts Machine Works

Fig. 16—Line cut of the Dilts refiner as used in the paper industry. Operating speed is 1800 r.p.m. Lubrication of ball bearings is maintained by a light bodied grease. Adequate means are provided to prevent entry of contaminating foreign matter into bearings.

Carbon Residue—Its Effect and Determination

There are a great many phases of industry wherein operating temperatures at the bearing elements may become so high as to cause chemical change of lubricants and deposition of more or less carbon which can normally be expected to remain in oil grooves or other parts of the lubricating system. This will be especially true in connection with the internal combustion engine, the air compressor, and in certain instances, the steam engine. Other examples of where this may occur will be in the operation of such machinery as the textile calender, the dryers in the paper industry or where kiln treating or metal working is practiced.

Inasmuch as carbon deposits may therefore be expected to develop into a decided detriment, in connection with the maintenance of effective lubrication, study of the manner in which they occur in petroleum lubricants and the methods of test for the carbon forming tendencies should be of interest.

The average petroleum product will be composed of from 83 per cent to 87 per cent carbon, with 11 per cent to 14 per cent hydrogen. The balance of any such product will include small quantities of sulfur, oxygen and in some types nitrogen according to the geological formation from which the oil originated.

Carbon, as an inherent component of all petroleum products, by reason of their complex hydrocarbon make-up, must remain as nearly as possible in this combined form if the products are to function effectively. Particular effort has been made by the petroleum industry to produce lubricating oils which will retain their original hydrocarbon formation in actual operation.

CARBON DEPOSITS

Chemical change is largely responsible for deposits of carbon plus dirt, as, for example, on the valves or in the discharge lines of an air compressor. It is impossible to get away from this phenomenon, for lubricating oils, regardless of their base or nature, will develop volatile products and carbon when subjected to temperatures considerably above the flash point. On the other hand, the extent of this reaction will depend upon the length of time the oil is exposed to such heat. It will also follow that with oils of the same degree of refinement, the one which remains in the engine or compressor cylinder or on the discharge valves the longest will form the greatest amount of carbon. Oftentimes a more volatile oil of low carbon content will be the most economical even though consumption is greater.

It is interesting to note, that analysis of many carbon deposits has proved them to include a considerable amount of dirt, the whole

being held together by gummy matter from decomposed oil, especially where the latter has been unsuited to the service involved.

Obviously, an oil having a wide range of distillation, high end point, or too great a viscosity is objectionable, inasmuch as, instead of vaporizing cleanly, it may undergo chemical change, as has been mentioned above,

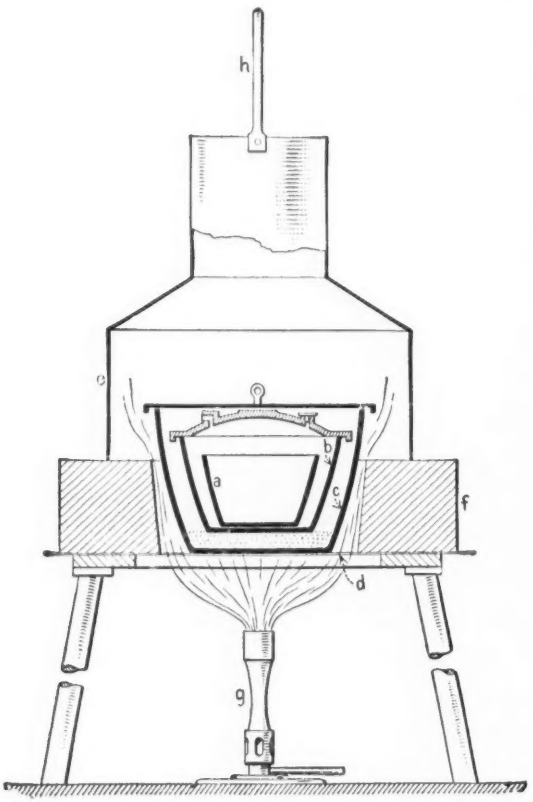


Fig. 17—Showing apparatus for determining carbon residue, as adopted by the American Society for Testing Materials. (a) indicates the porcelain crucible, (b) the Skidmore crucible, (c) the spun sheet iron crucible with cover, (d) the bare nichrome wire triangle (e) the circular sheet iron hood, (f) the asbestos block or hollow sheet metal box, and (g) the Meker type burner.

becoming sticky and collecting dirt brought in by the air. The slower this change or the greater the volume of oil involved, the more deposits will ultimately be developed with greater possibility of subsequent trouble.

Manner of Formation

In air compressor or internal combustion engine service, carbon in its true form may develop in the cylinders in a hard mass or it may be produced in the shape of dust and pass out with the air or exhaust. In the latter case, it will often collect in pockets, elbows, or on sharp edges and become mixed with dirt which has gained entry as well as with oil which has been vaporized in the cylinders, and later condensed at these points.

Inasmuch as carbon is a poor conductor of heat, when deposited in cylinders or around piston rings, it may become heated considerably above the temperature of the cylinder walls. This condition ultimately may be hazardous if allowed to continue. Furthermore, there will be a possibility of accumulations developing on the valves and valve seats, and in the ends of the cylinders. This may cause valves to leak, frequently resulting also in cutting of the latter and scoring of the cylinders.

Where deposits of dirt, gum, or carbon become localized in the valve passages and bends of piping of a compressor system to such an extent as to restrict the opening through which the compressed air has to pass, temperatures may be produced capable of eventually causing failure, especially if any part of the system is weak.

In view of the fact that distilled oils, where properly refined, show the least tendency toward direct carbonization and the development of carbonaceous matter, they are generally accepted as best suited to air compressor and internal combustion engine service. Furthermore, any such direct carbon as may be formed through excessive use of such oils is normally of a light, fluffy nature. Carbon deposits formed from improperly refined or unsuitable oils, on the other hand, are often of a hard, flinty nature. Any oil will accumulate dust if the air is dirty and no provisions are made for filtration or cleaning.

METHODS OF TEST

The determination of the carbon residue content for any lubricant can be accurately made according to the nature of the latter by the Conradson or Ramsbottom Method. The former has been adopted by the American Standards Association, the American Petroleum Institute, the American Society for Testing Materials, and in a modified form by the Institution of Petroleum Technologists in England. It is widely used by producers and refiners of lubricants in the United States. The Ramsbottom Method has been designated as an alternative method by the Institution of Petroleum Technologists in England.

As a brief introduction to these methods, it is well to state that each involves the external heating of a measured quantity of the oil within suitable apparatus wherein all vapors are driven off, until complete evaporation has been accomplished. The resultant residue in either the coking bulb of the Ramsbottom Method, or the crucible of the Conradson device, will be the carbon residue content of the original sample of oil. By careful weighing it can be expressed on a percentage basis in relation to the oil under test.

The above is only a generalized statement of how the results are attained. It will be of interest, therefore, to give the detailed construction and the method of procedure in connection with both the Conradson and Ramsbottom Methods.

The Conradson Method

According to the American Society for Testing Materials,* this involves (a) a porcelain crucible, located within (b) a Skidmore iron crucible. Both are in turn contained within a spun sheet-iron crucible, with a suitable cover. (See Fig. 17.)

In the bottom of the latter is placed a layer of dry sand, enough to bring the Skidmore crucible with a cover on it nearly to the top of the sheet-iron crucible. Below this crucible is a wire triangle with an opening small enough to allow it to serve as a support; (e) is a circular sheet-iron hood, provided with a chimney at the top as shown; (f) is an asbestos block or hollowed sheet metal box within which the arrangement of crucibles is located; (g) is a Meker type gas burner. More complete details on the above apparatus, with sizes and capacities, are shown on pages 53 to 56 of the report of Committee D-2 on Petroleum Products and Lubricants, 1932.

The procedure in the determination of carbon residue as recorded by the A.S.T.M., is as follows:

"Place two glass beads about 0.1 in. in diameter in, and include them in the weight of, the tared porcelain or silica crucible in which is accurately weighed 10 g. of the oil to be tested, free from moisture or other suspended matter. Place this crucible in the center of the Skidmore crucible. Level the sand in the large sheet-iron crucible and set the Skidmore crucible on it in the exact center of the iron crucible. Apply covers to both the Skidmore and the iron crucible, the one to the latter fitting loosely to allow free exit to the vapors as formed."

"On a suitable stand, place the bare nichrome wire triangle and on it the asbestos block or hollow sheet-metal box. Next, center the sheet-iron crucible in the block with its bottom resting on top of the triangle, and cover the whole with the sheet iron hood in order to distribute the heat uniformly during the process."

"Apply heat with a high strong flame from the Meker type gas burner so that the preignition period will be 10 minutes ± 1½ minutes (a shorter time may start the distillation so rapidly as to cause foaming or too high a flame). When smoke appears above the chimney, immediately move or tilt the burner so that the gas flame plays on the sides of the crucible for the purpose of igniting the vapors. Then remove the heat temporarily, and before replacing adjust by screwing down the pinchcock on the gas tubing so that the ignited vapors burn uniformly with the flame above the chimney but not above the wire bridge. Heat may be increased, if necessary, when the flame does not show above the chimney. The period of burning the vapors shall be 13 minutes ± 1 minute."

"When the vapors cease to burn and no further blue smoke can be observed, readjust the burner and hold the heat as at the beginning so as to make the bottom and lower part of the sheet iron crucible a cherry red and maintain for exactly 7 minutes. The total period of heating shall be 30 minutes ± 2 minutes which constitutes an additional limitation on the tolerances for the pre-ignition and burning periods. There should be no difficulty in carrying out the test exactly as directed with the gas burner of the type named, using city gas (about 550 B.t.u.) with the top of the burner about 2 inches below the bottom of the crucible. The time periods shall be observed with whatever burner and gas is used."

"Remove the burner and allow the apparatus to cool until no smoke appears, and then remove the cover of the Skidmore crucible (about 15 minutes). Remove the porcelain or silica crucible with heated tongs, place in the desiccator, cool and weigh. Calculate the percentage of carbon residue on the original sample."

Tolerances

"Weights of oil sample shall be accurate to within 5 mg. Tests shall be run in duplicate and repeated if necessary until the percentages of carbon residue differ by not more than 10 per cent from an average."

THE RAMSBOTTOM METHOD

In contrast with the Conradson method, discussion of the Ramsbottom method will be of interest. The apparatus involved and procedure are as follows*:

Apparatus

"The sheath shall be an iron tube, the closed end of which shall be flat, 3 inches in length, 1 inch in internal diameter, and approximately 1/16 inch thickness of wall."

"The coking bulb shall be blown from glass

*Report of Committee D-2 on Petroleum Products and Lubricants etc., 1932, under Designation D-189-30 for Carbon Residue of Petroleum Products.

*Standard Methods of Testing Petroleum and its Products. Second Edition 1929, P. 54, Institution of Petroleum Technologists.

tubing of 1 mm. wall thickness and shall be a sliding fit in the iron sheath. One end shall be rounded and the other drawn out to a capillary of 1.5 mm. internal diameter and 9.5 mm. in length. The distance from the base to the shoulder of the bulb shall be 38 mm. and the overall length from the base to the tip of the capillary shall be 57 mm."

Method

"The sheath shall be maintained at a constant temperature of 1020 degrees Fahr. (550 degrees Cent.) in a bath containing such a quantity of molten metal (lead) that the bottom of the sheath shall be 1 inch from the bottom of the bath and the sheath shall project not more than 1/8 inch above the surface of the molten metal. The temperature shall be controlled by a reliable pyrometer, accurate to ± 5 degrees Cent., which shall be placed in the bath as near as possible alongside the sheath, the end being 1 inch from the bath bottom. It is desirable that the pyrometer stem be fitted with a quartz sheath as protection against the deteriorating effect of the molten metal, and when using the type of pyrometer where the cold junction is at room temperature a zero adjustment should be made with one lead detached, it being advisable to check the zero before each experiment. The recording instrument should be protected from the heat radiated from the bath."

"A clean bulb shall be weighed and 3.75 to 4.25 grams of the oil introduced, the bulb being conveniently filled by inserting a glass capillary, suitably bent, and applying suction while the end of the bulb is immersed in the oil."

"The bulb containing the oil shall be placed in the sheath and allowed to remain for ten minutes after fuming has ceased. The bulb shall be re-weighed when cool, care being taken to remove any small particles of adhering metal before weighing."

"The bulbs may be cleaned after use by heating in a mixture of concentrated sulphuric acid and potassium hydrogen sulphate, care being taken to remove all traces of acid when finally washing with distilled water."

RELATIVE ADVANTAGES

Operation of the Conradson and Ramsbottom Methods of Test has developed a difference of opinion as to the oil viscosity range to which they may be adaptable. The former is regarded as the most flexible in this respect; authorities being of the opinion that it is applicable to testing of either lubricating or fuel oils of any viscosity. The Ramsbottom Method, however, is not unanimously favored for residual fuel oils.

The Conradson method is considered to be a more adaptable method for normal laboratory practice, due to the greater rapidity with which tests can be made, and also, the lower initial cost of the device, On the other hand, according to certain authorities, the Ramsbottom method enables easier control of variables such as temperature throughout the test. This is a most important factor. Obviously each method may, therefore, have advantages and disadvantages. It is not the purpose of this article, however, to indicate any preference, the purpose being rather to give an insight into the operation of each in connection with the ultimate determination of carbonaceous residues which may prove detrimental to effective lubrication.

CONCLUSION

The amount and nature of carbon residue which may be produced from any petroleum product will depend upon the boiling point, constitution and composition of the hydrocarbons present.

It is important to remember in this connection that increase in boiling point, as well as increase in viscosity, assuming that the same degree of refinement has been made,will result in an increase in carbon residue content. In other words, a lubricant of 80 seconds Saybolt viscosity, at 210 degrees Fahr., will normally show a higher carbon residue content than a product of say 50 seconds viscosity at the same temperature, provided, of course, that they have both been subjected to similar processes of refinement and have been made from the same type of crude.

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